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THE ENGINEER AND THE PROBLEM OF AËRIAL NAVIGATION.

BY REAR-ADMIRAL GEORGE W. MELVILLE, ENGINEER-IN-CHIEF OF THE UNITED STATES NAVY.

> "I talk of dreams
> Which are the children of an idle brain,
> Begot of nothing but vain fantasy,
> Which is as thin of substance as the air;
> And more inconstant than the wind."
> —SHAKESPEARE, "Romeo and Juliet."

IN earlier times many thoughtful men have given unqualified recognition to the uses and delights of the imagination. But could they see now, in the light of history, with what folly human nature has pushed a noble truth to the extreme, they would realize that much of its wisdom and grandeur has been obscured by the abuse of the imagination and undue revelling in its pleasures.

This fòlly has been always peculiarly manifest in natural science, whence it penetrates to the field of applied mechanics.

Outside of the proven impossible, there probably can be found no better example of the speculative tendency carrying man to the verge of the chimerical than in his attempts to imitate the birds, or no field where so much inventive seed has been sown with so little return as in the attempts of man to fly successfully through the air. Never, it would seem, has the human mind so persistently evaded the issue, begged the question and, "wrangling resolutely with the facts," insisted upon dreams being accepted as actual performance, as when there has been proclaimed time and again the proximate and perfect utility of the balloon or of the flying machine.

Notwithstanding the amount of accurate physical knowledge now possessed by man, and the unremitting efforts on the part of many earnest investigators, pursuing methods of observation and experiment, who have within recent years placed the study of the problem of Aërial Navigation upon a thoroughly scientific basis, it may be truly said that, so far as the hope of a commercial solution of the problem is concerned, man is to-day no nearer fulfillment than he was ages ago when he first dreamed of flying through the air.

Some of the investigators pursue truth for its sake alone, but most of them are spurred on by the hope of some practical application of the principles when they shall have been fully established. Any basis for a hope of practical application must rest in a careful analysis of the possibilities and limitations of both nature and man and the relations involved.

The problem of Aërial Navigation may be regarded in at least three aspects—from the viewpoint of physical science, from that of social science, and from that of purely speculative philosophy. Of these three, we know physical science to be the most exact; we know social science to be to a certain degree exact; and we know that purely speculative philosophy, from its great unreliability, has long since lost much of its caste and standing. From this it follows that, in a consideration of the problem, great importance would attach to the conclusions reached through an investigation of physical phenomena; that, in connection with such conclusions, some results of a study of social conditions would have to be noted; and that any opinion based merely on *a priori* argument would be entitled to slight attention.

The modern engineer, and especially the American engineer of to-day, may be regarded in at least two aspects: first, with regard to his qualifications for solving physical problems by his mathematical and mechanical knowledge and training, and, second, with regard to his position as a business man. In the first aspect, the engineer has been long generally recognized; but commercial necessities now so thoroughly shape and direct his labors that his business abilities should be particularly appreciated.

The engineer, as an important working force in a centre of intense activity, is to-day connected and identified with the manufacturer, with the organization and management of vast business enterprises, and with the solving of problems of capital and labor in the industrial world; and, generally speaking, he is an economist and a "social engineer." He is in close touch with the financier and business man, and knows much of their hopes and fears, their past efforts, present interests, and future prospects. The fully equipped engineer of to-day must be versed in the established facts and laws of physics, especially along mechanical lines, and in their industrial application; and he must possess a wide acquaintance with business principles and methods. He is the connecting link between the business world and the worlds of invention and science. Many engineers are scientists, inventors, business men, and engineers all in one; but the essential meaning of the word "engineer" to-day, in the United States, is that of a technical business man.

It may be readily inferred from what has been said that the engineer is peculiarly qualified to consider the problem of Aërial Navigation in its two most important bearings, physical and social; and the imaginative power which he must possess in order to be a successful designer of machinery and a commercial organizer, should be sufficient guarantee of his ability to conjecture as well as any man of intelligence the possibilities of commercial transportation through the air.

A calm survey of certain natural phenomena leads the engineer to pronounce all confident prophecies at this time for future success as wholly unwarranted, if not absurd.

M. Santos-Dumont can without doubt round the Eiffel tower and return to St. Cloud on a calm day, but no actual trial is needed to show that such a journey is impossible on many days, is always extremely dangerous, and of little or no practical use. The difficulty and danger are due, as has been often shown, to the inability of the balloon to maintain its shape.

In any balloon open at the bottom, as originally constructed, the resistance to collapse at the bottom is practically nothing, being no more than is offered by the weight of the fabric, as in the case of a simple curtain. At the top of a hydrogen-filled balloon twenty feet in diameter the resistance is only one and a half pounds per square foot. This will give way under the normal impact of an air current of only eighteen miles per hour; and as soon as collapse begins the case is aggravated by the concave surface presented to the wind. Metal frame-work within a balloon must seem of doubtful advantage when we consider the increase in weight, the fragile nature of the frame-work, and the large areas of unsupported fabric. The danger of rupture of the latter would be even increased by the presence of the framing.

Closing a balloon at the bottom and maintaining a slight pressure within it, is more promising. Hydrogen, which is the most buoyant gas available for inflation, under a pressure of ten pounds per square foot loses only about one-half of one per cent. of its buoyancy, and the balloon could resist the normal pressure of wind blowing at the rate of twenty-five miles per hour. The fabric of such a balloon twenty feet in diameter would, however, have to sustain a tension of not less than seventeen pounds per running inch. And here we meet a new difficulty; for, unless the pressure within the balloon is limited by means of a safety valve, the tension of the fabric will be increased nearly fourteen pounds for each hundred feet of ascent. The heavier fabric required by the closed balloon becomes still heavier as we increase the size of the balloon, and places it at a disadvantage as compared with the open balloon, which, in turn, even with its lighter weight and consequent greater carrying capacity, must be made of enormous size in order to carry sufficient propelling power to enable it to remain stationary in a wind blowing thirty-five miles an hour.

In a storm at sea, spars, masts, and even sailors are often carried away by the wind. Let there be pictured a craft one hundred times more fragile than a ship, and so circumstanced that the failure of any one of many of its parts will result in almost certain death to all on board. Such a craft may be fairly entitled "The Dirigible Balloon."

Relations that depend on mere size, important in all natural phenomena, are particularly so in the problem of aërial navigation. Such relations are so numerous and intricate that there is no easy way of bunching them all together and drawing correct inferences regarding them, as is so frequently done from the performance of balloons or of flying machines when they are constructed on a small scale for experiment. To say that the dirigible balloon becomes a matter of less difficulty as its size is increased is but a partial statement of the real case. Each phenomenon in its relation to the size must be considered by itself. It will be found that certain difficulties are lessened and others are increased by a change of size. Ways and means having been decided upon, it will be then manifest that one particular size has an advantage over all others. In the problem of navigating the air, there is imposed a minimum limit by the weight of the man to be carried. Certain phenomena, such as the frictional resistance of the air, make for a larger size, but the simpler and more important relations of mass and energy call for a small size.

One may even venture the general statement that, except when the controlling factor is skin resistance, as in swimming, the known relations of mass and energy are such that the problem of self-transportation increases in difficulty with size. There are many illustrations of this to be found in the animal kingdom. That the conditions are easier the smaller the size, is shown in a general way by the great varieties of insect life, there being more of these than of all other animals and plants combined. The very small insects appear to feel the attraction of gravitation no more than a floating particle of dust, which in turn may be said to passively navigate the air without the aid of any mechanism whatever—all of which tends to show how simple the problem may be to nature when relations permit. It is even doubtful whether the largest insects could fall from a sufficient height or project themselves against an obstacle with sufficient velocity to cause actual injury.

It may appear a rather bold statement to say that nature has gone as far as she can in evolving animals of large size, owing to the limitations imposed by gravitation and the materials at her command. Nevertheless this would seem to be borne out by certain facts. Thus, where weight is lessened or neutralized by the buoyancy of water, as in the case of crabs, nature uses the insect structure on a much larger scale than elsewhere. The same is true of animals having bony skeletons, though here the largest wading varieties have been long extinct.

All animals have special endowments of one kind or another; some are fleet of foot, others are fitted for climbing trees, and still others are great burrowers. Nature, in making these special endowments, is confined within comparatively narrow limits. She must work with such materials as phosphate of lime and muscular and other tissues, and depend for the special endowments on mere proportion and such devices as horns, claws and hoofs. Since nature is clearly impartial in the matter of these special endowments, let us suppose them to be eliminated. Not dwelling upon the point that the large animals, in this supposed case, will have an advantage in swimming, since this advantage has no relation to the problem being discussed, all animals will be then on an equal footing as regards their ability to get about, whether by running, jumping, or climbing. The flea, the rabbit, the man, the horse, and the elephant could, in a running high jump, just clear the same fence. In the matter of flight, it is fair to assume that each of these animals would need a free space of, say, one hundred times its own dimensions in order to practice the art. The flea would be able to jump clear across its space or fall through its height and scarcely feel a jar. He could, therefore, fly to his heart's content without the possibility of being hurt. The sparrow could hop at most through a twentieth of its field, and a fall from the height allotted to it would make it an easy prey for the actual cat. The sparrow's flight would be, therefore, not wholly free from danger. A fall through a fifth part of the space allotted to the man would certainly kill him; and yet his flights would be relatively of no greater length than those of the flea.

Coming now to the works of man, a careful analysis and comparison will show them to be limited precisely as are the works of nature. They may be larger, because he can use steel, where nature must be satisfied with phosphate of lime. Also, man has an advantage in being able to use rotating parts, such as the wheel. But the wheel and all other similar devices give him only a minor advantage. His principal advantage lies in his ability to use stronger materials, and this, if anything, will enable him to outstrip nature in the *size* of a flying machine; for we may be permitted to believe that nature has evolved as large a flying creature as is possible with the means at her command. Should man succeed in building a machine small enough to fly and large enough to carry himself, then in attempting to build a still larger machine he will find himself limited by the strength of his materials in the same manner and for the same reasons that nature has. The brain alone of the man-carrying artificial bird may be said to weigh one hundred and fifty pounds. The step from the largest flying creature evolved by nature to the smallest flying machine that will meet the wants of man is, therefore, a very long one. To span that step man has, to help him, only a few mechanical contrivances and the superior strength of steel. Almost every other condition is set against him.

From these considerations, it would seem difficult to name anything that may be possible, and yet upon analysis is found to be more circumscribed by limiting conditions, than is a flying machine capable of carrying a man. That the limitations as to size are being felt by experimenters is shown by the general tendency toward the adoption of the smallest possible size that will carry a human being.

If the foregoing are some of the important physical facts to be considered, it is needless to say that the engineer can see in them no confirmation of the predictions that frequently have been made of a commercial solution of the problem.

If the past is the best prophet, an unbiased review of what mechanical invention has done toward success, by the substitution of one form of aërial machine for another, would lead the engineer to say, also, that, far from supporting a hopeful view, it fills the mind with doubt. But no such review is needed here, since the possibilities of invention depend upon existing physical relations, and these do not seem to point to ultimate success, as we have seen.

Existing modes of transportation are the result of the development and perfection of crafts and vehicles known to prehistoric man. The dug-out and the two-wheeled cart are the historical germs from which have grown the steamship and the automobile; but where, even to this hour, are we to look for the germ of the successful flying machine? The kite is attached to the earth; the balloon and soaring machine, although they may not be said to be attached to the air, must yet obey its whim, and, in the long run, goes where it goes, if not dashed to the ground.

If the safe and speedy dirigible balloon and the successful flying machine are to be realities to-morrow, where is the preparation to-day? The dirigible balloon has reached a point where it seems that its future limits can be marked, and these limits would not be of sufficient range to include anything like success. The successful flying machine, to spring full-fledged from the ashes of present failure, would have to be a Phoenix.

The most logical interpretation of the present development of both the dirigible balloon and the flying machine would seem to be that "Aërial Navigation" is merging into an heroic sport.

Coupled with the prophecies for the commercial utility of the dirigible balloon and the flying machine, we hear predictions as to their extensive use in war.

It may be said, generally, as true of military science, that every great point of offence is met by a great point of defence, though a temporary advantage of one over the other has often occurred. A marked advantage on the side of either offence or defence in the future would have to grow out of scientific discovery and invention of a rare order; and it would partly revolutionize warfare. Since such an advantage would have to be developed gradually, it could not be kept secret, and when it reached the point of practical application in war, it would be possessed, in one form or another, by all the principal powers. They could be, therefore, upon an equal footing as regards their ability to use that advantage.

Applying these general truths to possible Aërial Warfare, for the sake of argument,—and remembering that wind and weather could not be counted on as being permanently favorable or adverse by either of two opposing forces,—we have as the most probable prediction:

The successful dirigible balloon, or the successful flying machine for war purposes, capable of carrying a man or men in addition to ammunition and ordnance, would be such epoch-making inventions as to be possessed by all the principal Powers. When fighting each other, the chances of such machines would be equal. In the case of their attacking land or sea forces, the chances would be exactly even for two great nations battling with each other. At least, we have no rightful reason to give, in advance, the preference to either nation, if they be equally matched; and when one is strong and the other weak, it matters not what the weapons may be, the chances are decidedly in favor of the strong.

The drifting and unmanned balloon, and the unmanned flying machine, would be possessed by all the principal Powers, who would be thus upon an equal footing as regards the use of such weapons. The balloon would be subject to the whim of the wind, and the flying machine would behave like an aimed but unguided rocket of greatly lengthened flight and increased carrying power, and as such both would be wholly unreliable and would be considered of secondary importance as aërial weapons. Their use would be exceedingly costly as compared to the damage they might possibly do to an enemy, and by reason of an unexpected change in wind and weather they might prove, in individual cases, a terrible boomerang to the army or navy using them.

What unmitigated evil to any great nation can be seen in these future weapons, admitting their possibility, it is very hard to discern, though such an idea seems to be entertained by those who love to speculate about the weird and morbid, who would make a vision of to-day the actual terror of to-morrow.

But while we may, for the sake of argument, consider what might happen if aërial warfare were possible, the existing physical relations that already have been considered seem to show that we have no right to expect such warfare, and that, so far as radical departures in military methods are concerned, "prophets whisper fearful change" all to no purpose.

It may be said, however, that in war heroic hazard is at a discount, and that the slightest success with aërial navigation in peace times may serve as a sufficient incentive for individual deeds of daring in the air, such as require the bravest hearts and the most courageous spirits.

Much is often claimed for the promotion of peace in the event of a successful aërial war-machine being perfected in the future, on account of added horrors of warfare and other considerations that will not so well bear investigation, but it is not easy to see how a new weapon of war, possessed by all the principal Powers, could bring about peace.

In his relation to the industrial world, the engineer may be said to be a vital link between the known and the unknown. He helps in the establishment of the knowledge of what is possible and impossible, of what is practicable and impracticable, in their physical, mechanical and commercial relations. His duty in connection with the encouragement of pure science and the application of its most general laws is to level the business world up to that high plane; and his duty in connection with the business world is to level the scientist or high-minded inventor down to an appreciation of the value of practical thought and action.

The engineer may be thus said to be the mediator and adjuster of differences, the interpreter of aims and ambitions, between the worlds of scientific theory and industrial pursuit. So necessary is the engineer to the true welfare and progress of a nation that the day shall soon come, if it is not already here, when his obligations to society will be so universally appreciated and understood that much lack of feeling and sympathy on his part for all classes of men will write "failure" across his name as a "social engineer," as surely as it is now written when he makes a mistake of any consequence in the purely technical work of his profession.

That his duties are most important and delicate, and that his responsibilities may be hardly measured, need not be said; and it is not to be expected that his judgment is unerring. But when he does err, it is rarely on the side of rashness, and all in all he may be considered as the safest guide that the business man may follow.

It need not be fully pictured what the engineer sees to-day in the social aspect of the undecided problem of Aërial Navigation—what he sees of the possibilities for pretension to infallible prophecy, for scientific error, for the pervading of the business world with false hopes, mechanical moonshine, and downright charlatanism.

The engineer lays no claim to final judgment upon physical possibility or impossibility—for no man has a right to such a claim; and though he does not relinquish his right to an approximately fixed opinion in the present which gives him the basis for positive action, he yet may hold a liberal attitude toward what, through further scientific experiment and correct deduction therefrom, Nature may reveal in the future.

But the worst thing that could happen would be a partial success for Aërial Navigation, in which case it would have all the insidious evil of a half-truth and be a commercial counterfeit susceptible of endless circulation. Companies would spring up like mushrooms, and thousands of people would lose the hoarded savings of years. The officers of a few of these companies would be self-deluded; but in the vast number of cases they would consist either of unprincipled promoters who take no personal risk, or else of veritable charlatans intent upon fleecing the public. In one or two instances, the treasuries of unwary Governments might be raided. All this without consideration of frequent and appalling catastrophe.

The engineer takes himself seriously, realizes the importance of his mission, and dwells upon his duty toward society. Accustomed to deal with facts and figures, he sees things in an exact and forceful way. Accustomed to deal with inexorable physical law, he has a keen perception of the dire consequence of error, and from this gets a strong realization of the wrong that a violation of moral or social law would create.

He tries to approximate the evil and total up the injury that an engineering sham will bring to the nation. He denounces, in unmeasured terms, any so-called mechanical device or unscientific pretension whose existence is a menace to the people's welfare—from the Keely motor to the claims for the great commercial utility of liquid air.

The engineer lives in an atmosphere of accomplishment and *control,* and has an abiding faith in the power of mankind to achieve fair results or to *check* vicious tendencies. The engineer in no way countenances nor has any sympathy with *laissez faire* when applied to mechanical shams. He sees in the worldly spirit of indifference that lets ignorance run its course, the deluded quickly come to grief, or intelligent men be tricked and snared, without any interference, a selfishness and moral turpitude that seem inhuman. So far as it is possible, he believes in checkmating the charlatan, in advising the ignorant, in opening the eyes of the deluded, and in warning the business man when likely to be imposed upon by unprincipled shrewdness.

Bearing in mind the possible formation of stock companies for meretricious ends, the wide-awake engineer notes at all times the agitation of the problem of Aërial Navigation, and persistent public exploitation of experiments whose value is doubtful and of prophecy whose basis is insufficient; and he feels that in such exaggeration there is great danger to the best interests and immediate pursuits of the people.

The engineer hopes that the earnest investigators of the problem, whether they be scientists, inventors, or brother engineers, or, in some cases, all three in one, to whose keeping this problem is to be confided, may so follow the scientific method that in the day to come, when the actual results of their combined labor are seen in full, the solution may be so satisfactory that there can be no doubt as to actual success, or actual failure, or actual limited practicability,—whichever may prove eventually to be the case.

There is one engineer whose opinion at the present hour, after a consideration of some of the more important physical and mechanical facts involved, and after noting, in connection with the conclusion to which such consideration has led, certain social conditions, is that there is no basis for the ardent hopes and positive statements made as to the safe and successful use of the dirigible balloon or flying machine, or both, for commercial transportation or as weapons of war, and that, therefore, it would be a wrong, whether wilful or unknowing, to lead the people and perhaps governments at this time to believe the contrary; and he, therefore, asked to be permitted to put his opinion thus before the readers of this REVIEW.

It has been always the function of science to clip the wings of fancy; and, as it did so, it has revealed a "fairy land" more wonderful than man could conceive, and has enabled him to attain a material comfort and happiness undreamt of. It is, therefore, not unreasonable to suppose that, if in the future physical discoveries actually show this now undetermined art to possess no commercial utility or military value, and to involve too much difficulty and danger as a sport to be universally indulged in, science will have revealed a glimpse of practical possibilities which, in their realization, shall surpass all present dreams.

GEO. W. MELVILLE.